TECHNICAL MANUAL
TM 5-826-1
AIR FORCE MANUAL
AFM 88-24, Chap. 1

HEADQUARTERS
DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, DC *12 August 1988*

AIRFIELD PAVEMENT EVALUATION CONCEPTS

LIST OF TABLES

*This manual supersedes TM 5-826-1, October 1979, and TM 5-827-1/AFM 88-24, Chapter 1, March 1981.

AIRFIELD PAVEMENT EVALUATION CONCEPTS

Purpose. This manual presents general con-
pts for the evaluation of the load-carrying capac-
r of pavements used, or to be used, for support of
rcraft. An evaluation is conducted to assess the
lowable traffic that a pavement can sustain for
ven loading conditions or the allowable load for
given amount of traffic without producing unex-
cted or uncontrolled distress.

Scope. This manual is for use in evaluating
rmy and Air Force airfields and heliports, and is
plicable to conventional type pavements. The
iidance can also be applied to aggregate surfaced
rips, assault and expedient surfaced fields, pave-
ents on permafrost, etc., but these require sup-
emental information and in some cases substan-
al modification of methods.

. **References.** Appendix A contains a list of
eferences used in this document.

. **Relation of design to evaluation.** The design
f a pavement requires selecting materials with
ie necessary strength, and placing them at the
roper thickness, density, and depth, so that the
avement will be capable of carrying an antici-
ated number of passes of a given load. Because of
ariations in materials and placement conditions,
he as-constructed pavement may have strengths
nd thicknesses of layers greater or less than
ontemplated in design. Also, with time, usage,
nd environmental impacts, the elements of a
avement contributing to its strength can be sub-
ect to some change. Thus, an evaluation will
letermine the physical properties of a pavement as
ctually built or in its current condition and
establish therefrom the pavement's traffic/load
supporting capacity.

5. **Concepts.** The primary function of a pavement is to spread and distribute the wheel loads placed on it. Each airfield or landing strip has its own natural soil and environmental conditions, and the in situ soils must ultimately sustain the stresses resulting from loads applied to the pavement. Since the strengths of native soils can vary widely from site to site, the ability to support loads also varies widely. However, except in unusual cases, aircraft tire loads cannot be satisfactorily sustained directly on the native soils.

a. Pavement structure. Pavement design and evaluation are concerned with determining the capability of the pavement structure to reduce the load intensity to a magnitude the airfield site soils can sustain. The larger the load at the surface and the smaller the tire contact area, or conversely the higher the contact pressure, the stronger or thicker the pavement structure must be to distribute load and reduce load intensity (pressure or stress) to that which the native soil can accept. Layered flexible pavements distribute load by broadening the effective area supporting the load, from the tire contact area on the surface to a wider area on the base, a still wider area on the subbase, and so on. Each layer must be of a quality to sustain the load intensity or stress it must accept, and each must be thick enough to broaden or distribute the load and reduce intensity to that which its supporting layer can sustain. Rigid pavements are stiffer and have a "beam action" or flexural capability which spreads or distributes load more widely, so these pavements can be much thinner than flexible pavements. However, thickness, flexural strength, and other quality aspects must be assessed for evaluation.

b. Loadings. Early aircraft were primarily supported on only two main landing gear wheels, referred to as "single" wheels. The foregoing pavement structure discussions have a single-wheel load as example. With the large increases in aircraft gross weights, landing gear have changed to twin (2 per strut) wheel loadings, to twin-tandem (4 wheel) loadings, and to more complex (16 and 24 main gear wheels, extra "belly" gear) wheel support systems. The two main wheels of single-wheel aircraft are generally spaced far enough apart that there is no significant overlap of the distributed loads for even very thick pavement structures protecting weak subgrades. For twin wheels, however, and closely spaced tandem wheels or complex wheel groups, the patterns of distributed surface loadings at and near the bottom of pavement structures overlap so that the intensities (pressures or stresses) recombine between adjacent wheels. This recombining effect of load intensities is greater as the adjacent wheels become closer. However, the combining effect is less for strong subgrades requiring only relatively thin pavement structures than for weak subgrades requiring thick pavement structures. This is a significant factor in pavement evaluation regarding the gross weight and wheel configuration of using aircraft.

c. Load repetitions.

(1) Repetitions of load or aircraft passes is an aspect of structural capacity. A pavement capable of sustaining a certain aircraft loading on a regular repeating basis for some "design" life of the

facility (commonly 20 years) can sustain repeated application of a larger loading, but for a reduce pavement life (less number of passes).

(2) It follows that an evaluation of the structural capacity of a pavement may determine not only a maximum allowable number of repetitions for a specific loading, but also a maximum allowable loading for a given number of repetitions of traffic.

(3) This pattern of load and repetitions implies that a single application of a given load can be considered to represent a number of applications of a load of another magnitude. The number of applications can therefore be taken as the equivalent applications of one load to another. These equivalent applications or equivalencies will normally be uneven or fractional numbers. For example, one application of a load which is 20 percent heavier than another, when applied to a pavement, may be considered equivalent to 6.5 applications of the smaller load or, one application of the lighter load may be considered equivalent to 0.15 applications of the larger load.

(4) Extension of this concept permits the reduction of an array of loadings and the repetitions of each, to an equivalent number of repetitions of a single selected load. By stating each loading in the array as equivalent applications of a selected basic load, multiplying each by its actual number of repetitions, and accumulating the total, the total applied traffic can be stated as equivalent repetitions (or applications) of the selected basic loading. This methodology is an important adjunct to evaluation since it permits comparisons of cumulative past traffic, design traffic, traffic associated with load evaluation, and increments of pavement life associated with overloading.

d. Pavement useful life. Pavement design and evaluation have long included a concept of useful life. At first, pavements were designed somewhat vaguely to last about 20 years. With recognition that pavements are structurally limited by some pass/load combination, it becomes necessary to establish some useful life before any pass/load limitation can be meaningfully applied. To determine, for instance, that a 300,000-pound twin-tandem gear loading can be sustained for 63,000 passes represents a severe overloading if passes are applied at 100 per day (approximately 2 years) or significant underloading if passes are at only 1 per day (approximately 170 years). At 10 per day it represents about a 20-year useful life. This simple example is further complicated by mixed traffic and loadings, by the portion of useful life already consumed by past traffic use, and by past cumulative traffic applied prior to major pavement upgrading such as an overlay. Thus, evaluation results may be used for determination of the total and of the remaining pavement useful life and is required for an Army evaluation.

6. Evaluation procedure.

a. Steps in the procedure. Fundamentally, evaluation procedures are the reverse of design procedures and consist of six basic steps:

(1) Thorough study of all existing information regarding design, construction, maintenance, traffic history of the pavements, results of physical-property tests of the pavements, and weather records for the vicinity.

(2) Determination of pavement condition by formal Pavement Condition Index (PCI) methods as delineated in AFR 93-5 wherever possible, but as a minimum by direct visual inspection.

(3) Determination of the scope, validity of available data, and need for additional information or tests.

(4) Determination of pavement element characteristics and/or pavement response to loading for input to the evaluation method using one of the following procedures:

(*a*) Selection of strength, thickness, and other behavioral values considered representative of the flexible or rigid pavement surfacing, base course, subbase course, and subgrade from available data.

(*b*) Opening test pits in selected representative locations for determination of material characteristics, layer thicknesses, soil strengths, and moisture-density conditions.

(*c*) Nondestructive procedures which develop the stiffness modulus (dynamic or impulse) of the overall pavement section as a basis for evaluation.

(*d*) Nondestructive methods which measure the deflection basin response to loading, and determine the pavement layer moduli by matching the deflection basin with an elastic layer model.

(*e*) Nondestructive testing systems using wave propagation and elastic theory for determination of layer stiffness moduli as a basis for evaluation.

(5) Determination of load-carrying capacity of the airfield pavements through the application of the evaluation criteria using representative pavement properties. In this regard, load-carrying capacity implies allowable load for selected repetitions or allowable repetitions for selected loadings.

(6) Assignment of an overall field evaluation based on the load-carrying capacity of the weakest pavement facility considered essential to the operation of the airfield.

b. Decision regarding additional tests. The decision as to the necessity for obtaining additional

ɜt data at the time of the evaluation or as to the ɜans of evaluation to be employed rests with the aluating engineer. In many cases, and particurly when relatively new pavements are being nsidered, design and construction control data e sufficient for the evaluation. For older pavements or in cases where the applicability of available test results is in doubt, additional tests are ısirable. Where circumstances preclude conductg these additional tests, physical property values ıould be assigned on the most realistic basis ıssible, with comments by the evaluating engiɜer on the limitations associated with the values ɜed.

Site data. In addition to test data on the ıysical properties of the pavement elements, it is ɜsirable to obtain the following general information regarding the site. Much of the information ın be obtained from records of preliminary investigations and from the design analysis if the irfield was constructed by the US Army Corps of ngineers. Other types of information that should e obtained are as follows:

a. Geographical location. The geographical location of the airfield can be determined using existıg engineering data normally furnished by the sing agency.

b. Geology. The general geology of the vicinity ʼill be determined as it applies to the soils at the irfield. The general type of soil deposition (e.g., lluvial, residual), the parent rock from which the oil is derived, and other pertinent information ʼill be identified. Aerial photographs showing ertinent features of the area will be secured when vailable. Information can be obtained from US ǝeological Survey publications and from state ;eological departments, subsurface exploration ompanies, and similar organizations. Soil types an be determined from such sources as Departnent of Agriculture soil maps, state highway lepartments, and well logs.

c. Drainage and ground-water conditions. First, he general surface-drainage system for the area vill be ascertained. The natural drainage patter :an be established from contour maps published b :he US Geological Survey, the National Ocean: ınd Atmospheric Administration, or the Defens Mapping Agency. Detailed information will k :ollected concerning drainage at the airfield, iı :luding descriptions of any drainage installatior ınd shoulder slopes, and whether excessive veget: :ion or soil has built up along the pavement edgı sufficiently to pond water on the pavements. Tł lepths to ground-water tables in the vicinity aı at the airfield property should be determined, aı the presence of any perched water tables in tł airfield subgrade will be noted. Information concerning ground-water tables can be obtained from well logs, cuts or borings in the vicinity, and the location of springs and seeps.

d. Climatic data. Information on climatic data can be extracted from routine National Weather Service publications and from records of the airfield weather station. For the period of record, the climatic data should include average daily maximum and minimum temperatures for each month, average annual rainfall, freezing index, average humidity, and description of the prevailing winds.

e. Maintenance. Detailed information will be obtained on the maintenance performed on each facility. All the dates of application of such items as seal coats, surface treatments, and patches will be ascertained, and the reason for performing the work will be explained in all possible detail. Files of the Facilities Engineer, Base Civil Engineer, or responsible construction office should contain this information.

f. Current condition of pavements. A detailed survey will be made of the pavement surface on all facilities. Procedures for conditions surveys of existing pavements are presented in AFR 93-5 for Army and Air Force use.

g. Airfield traffic data. For a pavement evaluation to be meaningful, it is essential to have some measure of normal or expected traffic in terms of repetitions and loading characteristics. Thus, the traffic data collected need to include the type of aircraft, gross weight, and typical operating weights of each type aircraft regularly using the airfield. Cumulative numbers of operations by type of aircraft are needed for each month since the facility was activated or since the latest evaluation was made as well as the distribution of traffic on the various

in connection with airfield evaluation, reveal that airfields can be evaluated to:

(1) Determine the number of repetitions of an aircraft that can use a pavement at a designated gross weight.

(2) Determine the allowable gross weight of an aircraft that can use a pavement for a given number of repetitions.

(3) Determine what effect past aircraft operations have had on pavement life in terms of percent life used.

(4) Determine the remaining life of the pavement for anticipated future aircraft operations.

b. Aircraft grouping for evaluation. To reduce calculations and simplify the evaluation procedure, operational aircraft have been divided into 4 classes for Army evaluation and 13 aircraft groups designated by an Aircraft Group Index for Air Force evaluations as shown in tables 1 and 2, respectively. As noted, the tables contain a listing of all appropriate operational aircraft that may be expected to use Army or Air Force airfields for various purposes. It is not feasible to evaluate for each specific aircraft, so a controlling aircraft was selected for each landing assembly configuration where more than one aircraft was involved as indicated in tables 1 and 2. A description of each controlling landing gear assembly is shown in table 1 for Army aircraft and table 3 for Air Force aircraft.

c. Aircraft traffic. On most military airfields, movements of aircraft follow typical patterns, and the amount of traffic on a pavement can be estimated from the number of landings and takeoffs on the runways. For evaluation purposes, the traffic records should be converted into passes. An aircraft pass is the passage of an aircraft on the pavement facility being evaluated. For a runway, passes are considered to be the number of aircraft takeoffs, excluding touch and go operations. For taxiways and aprons, passes are considered to be the number of aircraft movements that traffic the taxiway or apron. At single-runway airfields, the pass level for the runway, taxiway, and apron should be the same.

9. Evaluation.

a. Army airfields. Evaluations indicating the allowable pass/load relationship will be made for each aircraft in Class I, II and III (table 1). When not restricted by length of the aircraft runways, the evaluation for aircraft Class IV will also be included. Evaluations for Class III and IV pavements will include all gear configurations shown in table 1. The evaluation will be made for each of the aircraft loadings indicated in table 1 according to the applicable pavement class. When sufficient past traffic information is available, an estimation of the remaining life of the pavements for future aircraft operations should also be made. In addition, the US Army as a result of its evaluations requires that overlay thickness requirements be determined and included in the evaluation report along with maintenance requirements for day-to-day traffic. Design requirements are contained in TM 5-825-2 and TM 5-825-3 for flexible and rigid pavements, respectively.

b. Air Force airfields. Evaluations indicating the allowable pass/load relationship will be made for each aircraft group index (table 2). Characteristics of the controlling aircraft for each group are shown in table 3. The allowable load for Air Force airfields will be determined for six pass intensity levels based upon the aircraft group index as shown in table 4. Pass intensity levels I–IV are for normal conditions. Pass intensity levels V–VI are for frost melting periods. Air Force airfields may also be evaluated to determine the allowable number of passes for each of the aircraft loadings indicated in table 5 according to the aircraft group index.

10. Nondestructive evaluation. The procedure for the determination of allowable pass/load relationships of pavement systems using the nondestructive testing technique is discussed in TM 5-826-2/AFM 88-24, Chap. 2 and TM 5-826-3/AFM 88-24, Chap. 3. This procedure makes it possible to perform rapid evaluations with a minimum of interference to normal airfield operations.

11. The Aircraft Classification Number/Pavement Classification Number (ACN/PCN) method. This method reports aircraft weight bearing capacity. There is a need and a requirement for reporting the aircraft weight bearing capacity of airfield pavements as determined by evaluation. The Defense Mapping Agency publishes weight bearing limits in a Flight Information Publication for civil and international use. The intent is to provide planning information for individual flights or multiflight missions which will avoid either overloading of pavement facilities or refused landing permission. The collective information is also used by the aircraft industry in determining landing gear characteristics for new aircraft or for acquisition of aircraft suitable for use on airfields which must support them.

a. The International Civil Aviation Organization (ICAO) (1981, 1983) has devised the ACN/PCN method as an effective, simple, and readily comprehensible means for reporting aircraft weight-bearing capacity of airfields. The United States, as a cooperating ICAO nation, has agreed to report

Table 1. Aircraft identification by pavement class

Pavement Class and Controlling Landing Gear Characteristics	Aircraft	Loads for Determining Allowable Passes, kips
Class I: Single wheel, less than 100-psi tire pressure, 70 square inch tire contact area	OV-1*, U-8, H-34, YAO-1,	5, 10, 15, 20, 25
Class II: Twin wheel, 18-inch center-to-center spacing, 106-square inch tire contact area	CH-54*, CH-47, UH-60, A-7	20, 25, 30, 40, 50
Class III: Single tandem, 60-inch center-to-center spacing, 400-square inch tire contact area	C-130*	110, 135, 155, 175, 200
Single wheel, 100 psi, 272-square inch tire contact area	C-123	
Twin wheel, 26-inch center-to-center spacing, 165-square inch tire contact area	C-9*, C-119, C-54, C-131	
Class IV: Twin tandem, 38- by 48-inch, 208-square inch tire contact area	C-141	240, 290, 320, 350, 390
Dual twin-delta tandem, 285-square inch tire contact area	C-5A	350, 450, 550, 650, 800

* Controlling aircraft.

airfield weight bearing limits by this method, and at the present time the airfield weight-bearing limits will be reported in evaluation reports.

b. Using the ACN/PCN method as prescribed by ICAO (1981, 1983) it is possible to express the effect of individual aircraft on different pavements by a single unique number which varies according to pavement type and subgrade strength. This number is the aircraft classification number. Conversely, the load-carrying capacity of a pavement can be expressed by a single unique number without specifying a particular aircraft. This number is the pavement classification number. The ACN and PCN are defined as follows:

(1) *ACN* is a number which expresses the relative structural effect of an aircraft on different pavement types for specified standard subgrade strengths in terms of a standard single-wheel load.

(2) *PCN* is a number which expresses the relative loadcarrying capacity of a pavement in

Table 2. Air Force aircraft group index

1	2	3	4	5	6	7	8	9	10	11	12	13
C-23*	F-15*	F-111*	C-130*	C-9*	T-43*	B-727*	E-3*	C-141*	C-5*	KC-10*	E-4*	B-52*
C-12	A-7			C-7	737	C-22	707	B-1		DC-10	747	
C-21	A-10			DC-9			C-135	B-757		L-1011	VC-25	
A-37	C-20			C-140			KC-135			C-17		
	F-4						VC-137					
	F-5						DC-8					
	F-14						EC-18					
	F-16						A-300					
	F-100						B-767					
	F-101											
	F-102											
	F-105											
	F-106											
	T-33											
	T-38											
	T-39											

* Controlling aircraft.

Table 3. Characteristics of controlling aircraft landing assembly

Aircraft Group Index	Controlling Aircraft	Landing Assembly
1	C-23	Single wheel, tricycle, 100-psi tire pressure
2	F-15	Single wheel, tricycle, 86 square inch contact area
3	F-111	Single wheel, tricycle, 241-square inch contact area
4	C-130	Single-tandem-wheel assembly, tricycle, spacing 60 inches, 400-square inch contact area
5	C-9	Twin-wheel assembly, tricycle, spacing 26 inches, 165-square inch contact area
6	T-43	Twin-wheel assembly, tricycle, spacing 30.5 inches, 174-square inch contact area
7	B-727	Twin-wheel assembly, tricycle, spacing 34 inches, 237-square inch contact area
8	E-3	Twin-tandem-wheel assembly, tricycle, spacing 34.5 by 56 inches, 218-square inch contact area
9	C-141	Twin-tandem-wheel assembly, tricycle, spacing 32.5 by 48 inches, 208-square inch contact area
10	C-5	Twin-delta-tandem-wheel assembly, tricycle, spacing 34 by 53 by 65 inches, 285-square inch contact area
11	KC-10	Twin-tandem-wheel assembly, tricycle, spacing 54 by 64 inches, 294-square inch contact area
12	E-4	Twin-tandem-wheel assembly, tricycle, spacing 44 by 58 inches, 245-square inch contact area
13	B-52	Twin-twin-wheel assembly, bicycle, spacing 37 by 62 by 37 inches, 267-square inch contact area

Table 4. Pass levels for Air Force evaluation

Pass Intensity Levels	Number of Passes for Aircraft Group Index 1-3	4-12	13
I	300,000	50,000	15,000
II	50,000	15,000	3,000
III	15,000	3,000	500
IV	3,000	500	100
V	300,000	50,000	15,000
VI	50,000	15,000	3,000

terms of a standard single-wheel load. The system is structured so that a pavement with a particular PCN value can support, without weight restrictions, an aircraft which has an ACN value equal to or less than the pavement's PCN value. This is possible because ACN and PCN values are computed using the same technical basis.

c. ACN values will normally be provided by the aircraft manufacturers. The ACN has been developed for two types of pavements, flexible and rigid, and for four levels of subgrade strength.

d. The PCN numerical value for a particula pavement is determined from the allowable loac carrying capacity of the pavement. The allowabl load rating can be determined by applying th principles contained in TM 5-826-2/AFM 88-24 Chap. 2 and TM 5-826-3/AFM 88-24, Chap. 3. Ir determining the allowable load, such factors as frequency of operations and permissible stress levels should be taken into account. Once the

Table 5. Loads for Air Force evaluation

Aircraft Group Index	Loads for Determining Allowable Passes, kips
1	5, 10, 15, 20, 25
2	10, 20, 50, 70, 90
3	50, 65, 80, 100, 120
4	75, 100, 125, 150, 175
5	25, 50, 75, 100, 125
6	50, 70, 90, 110, 125
7	75, 125, 150, 175, 225
8	125, 175, 225, 300, 350
9	200, 275, 350, 425, 500
10	350, 450, 550, 650, 800
11	250, 350, 450, 500, 600
12	350, 450, 600, 700, 800
13	200, 275, 350, 425, 500

allowable load is established, the determination of the PCN value is a process of converting that load to a standard relative value. The allowable load to use for Army evaluations is the maximum allowable load of the most critical aircraft that can use the pavement for the number of equivalent passes expected to be applied for the remaining life. The allowable load to use for Air Force evaluations is to be based on 50,000 passes of the C-141 aircraft. Criteria for converting allowable loads to PCN values are presented in TM 5-826-2/AFM 88-24, Chap. 2 and TM 5-826-3/AFM 88-24, Chap. 3.

e. The PCN value is for reporting pavement strength only. The PCN value expresses the results of pavement evaluation in relative terms and cannot be used for pavement design or as a substitute for evaluation. Pavement design and evaluation are complex engineering problems which require detailed analyses. They cannot be reduced to a single number.

12. Evaluation reports. In the preparation of an airfield pavement evaluation report, the format and instructions presented in TM 5-826-4 will be followed for Army reports and AFR 93-5 will be followed for Air Force reports. These instructions require evaluation of the allowable passes and loadings for each of the classes of Army airfields or for each of the Air Force aircraft group indexes. Evaluation details for flexible and rigid pavements are presented in TM 5-826-2/AFM 88-24, Chap. 2, and TM 5-826-3/AFM 88-24, Chap. 3. Evaluation details for frost conditions are presented in TM 5-818-3/AFM 88-24, Chap. 4.

APPENDIX A
REFERENCES

Government Publications.

Departments of the Army and the Air Force

AFR 93-5	Airfield Pavement Condition Survey and Evaluation Report
TM 5-818-3/AFM 88-24, Ch. 4	Pavement Evaluation for Frost Conditions
TM 5-825-2/AFM 88-6, Ch. 2	Flexible Pavement Design for Airfields
TM 5-825-3/AFM 88-6, Ch. 3	Rigid Pavements for Airfields
TM 5-826-2/AFM 88-24, Ch. 2	Airfield Flexible Pavement Evaluation
TM 5-826-3/AFM 88-24, Ch. 3	Airfield Rigid Pavement Evaluation
TM 5-826-4	Army Airfield—Heliport Pavement Reports

Nongovernment Publications.

International Civil Aviation Organization, P.O. Box 400, Montreal, Quebec, Canada H3A2R2

Amendment Number 35 to the International Standards and Recommended Practices, Aerodromes, Annex 14 to the Convention of International Civil Aviation, March 1981.

Aerodrome Design Manual, Part 3 Pavements, Doc 9157-AN/901 Second edition, 1983

The proponent agency of this publication is the Office of the Chief of Engineers, United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) direct to HQDA (CEEC-EG), WASH, D.C. 20314-1000.

By Order of the Secretaries of the Army and the Air Force:

CARL E. VUONO
General, United States Army
Chief of Staff

Official:

R. L. DILWORTH
Brigadier General, United States Army
The Adjutant General

LARRY D. WELCH
General, United States Air Force
Chief of Staff

Official:

WILLIAM O. NATIONS, Colonel, USAF
Director of Information Management and Administration

Distribution:
Army: To be distributed in accordance with DA Form 12-34B, requirements for Army Airfield Pavement Engineering And Design
Air Force: F

*U. S. GOVERNMENT PRINTING OFFICE: 1988-201-422:80020